WATER BALANCE ANALYSIS
PROPOSED RESIDENTIAL DEVELOPMENT

613 Helena Street, Fort Erie, Ontario

Prepared for:

SS WELLAND INC.

4080 Confederation Parkway, Unit 701
Mississauga, ON L5B 0G1

Prepared by:

HLV2K ENGINEERING LIMITED
A Consulting Engineers Company

2179 Dunwin Drive, Unit 4
Mississauga, Ontario L5L 1X2

Project No. 2100394AG

February 17, 2022

February 17, 2022 Reference No.: 2100394AG

SS Welland Inc.
4080 Confederation Parkway, Unit 701
Mississauga, ON L5B 0G1
L5B 0G1

Attention: Mr. Hunain Siddiqui
Email: hunain@emrahomes.ca

RE: Hydrogeological Consulting Services for Proposed Development
613 Helena Street, Fort Erie, Ontario

Dear Mr. Siddiqui,

HLV2K Engineering Limited (HLV2K) is pleased to provide the Water Balance Analysis Report for the above-mentioned project. We trust that this information meets your present requirements. If we can be of additional assistance in this regard, please contact this office.

For and on behalf of HLV2K Engineering Limited,

K. Mohamadi

Kourosh Mohammadi, Ph.D., P.Eng.

President and Principal Hydrogeological Engineer

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1 INTRODUCTION

HLV2K Engineering Limited (HLV2K) was retained by SS Welland Inc. (the Client) to complete a water balance assessment to evaluate the recharge rate for pre- and post-development conditions at the project site located at 613 Helena Street in Fort Erie, Ontario (the Site). The Site considered for development is approximately 8.15 hectares (ha) in area and is currently occupied by a two-storey residential dwelling and associated garage, a two-storey barn and two storage buildings (The site buildings covered approximately 15% of the total Site area). The western portion of the Site is occupied by a forested area. The Site location is shown on **Figure 1**. This report is intended to provide the water balance analysis for pre and post proposed development.

The proposed development would consist of seventeen blocks (17) blocks including 54 2-storey townhouses, 62 bungalow townhouses, storm pond, landscape, roads and walkways. Draft plan of subdivision shows the location of these blocks and features provided in **Appendix A**.

2 WATER BALANCE

When precipitation (P) occurs, it can either run off (R) through the surface water system, infiltrate (I) to the water table, or evapotranspire (ET) from the earth's surface and vegetation. The sum of R and I is defined as the water surplus (S). When long-term averages of P, R, I, and ET are used, there is no net change in groundwater storage (ST). On a yearly basis, however, there is a potential for small changes in ST.

The annual water budget can be stated as,

$$P = ET + R + I + ST$$

The monthly averages of P and temperature (T) were collected from Environment Canada data. Based on the physiographic setting and proximity to weather stations, the Fort Erie Station (Station ID 6132470) located approximately 2.2 km southwest of the Site chosen as the most representative precipitation and temperature data

Climate Normals are arithmetic calculations of observed climate values over a specified time period and are used to describe the climatic characteristics of a location. Real-time values, such as daily temperature, may be compared to the "climate normal" to compare departures from the "average". The Canadian Climate Normals are calculated based on World Meteorological Organization (WMO) Standards. The WMO considers 30 years sufficient to eliminate year-to-year variations. The most recently published 30-year period from Environment Canada is January 1981 to December 2010.

In addition, the WMO established that normals should be arithmetic means calculated for each month of the year from daily data. To qualify, temperature data, soil temperatures and evaporation must fit the following rule: "If more than 3 consecutive daily values are missing or more than 5 daily values in total in a given month are missing, the monthly mean should not be computed and the year-month mean should be considered missing." This is referred to as the "3/5" rule. For total precipitation, degree-days, and "days with" calculations, no missing days are allowed.

2.1 Thornthwaite Monthly Water-Balance Model

The Thornthwaite water balance (Thornthwaite, 1948; Mather, 1978; 1979) uses an accounting type procedure to analyze the allocation of water among various components of the hydrologic cycle. Inputs to the model are monthly temperature, precipitation and the site latitude. Outputs include monthly potential and actual evapotranspiration, soil moisture storage, soil moisture storage change, surplus, and runoff. For ease of calculation, an Excel spreadsheet was developed. This water balance was prepared according to the "Hydrogeological Assessment Submissions: Conservation Authority Guidelines to Support Development Application (2013).

2.2 Pre-Construction Water Balance

To predict water balance elements the 30-year average weather data was used. The detailed calculations are presented in below sections.

Precipitation (P)

Based on the 30-year average (1981-2010) for the Fort Erie meteorological station, the average precipitation is about 1051.5 mm/year. The monthly precipitation distribution is presented in **Table B.1** of **Appendix B**.

Storage (ST)

Long-term annual change in storage is 0, although there is some variation on a monthly basis. It should be noted that for the topography, soil conditions (silty sand till to sandy silt till) and vegetative cover (moderate to deep rooted crops), the maximum soil moisture storage was estimated at about 250 mm according to Table 3.1 of MECP Stormwater Management Planning and Design Manual (2003).

Evapotranspiration

Calculated potential evapotranspiration (PET) based on the Thornthwaite monthly water balance model is about 607 mm/year, or about 58% of the total precipitation. The actual evapotranspiration is calculated based on a potential evapotranspiration (PET) and soil-moisture-storage withdrawal (SMW). PET is estimated from monthly temperature and is defined as a water loss from a homogeneous, vegetation covered area that never lacks water (Thornthwaite, 1948; Mather, 1978). In Thornthwaite water balance, PET is calculated using Thornthwaite Method (Ponce, 1989). The method is based on an annual temperature efficiency index J, defined as the sum of 12 monthly values of heat index I. Each index I is a function of the mean monthly temperature T, in degrees Celsius, as follows:

$$I = \left(\frac{T}{5}\right)^{1.514}$$

Evapotranspiration is calculated by the following formula:

$$PET(0) = 1.6\left(\frac{10T}{J}\right)^{c}$$

in which PET(0) is the potential evapotranspiration at 0^{o} latitude in centimeters per month; and c is an exponent to be evaluated as follows:

$$c = 0.000000675J^3 - 0.0000771J^2 + 0.01792J + 0.49239$$

At the latitude other than 0^{o} potential evapotranspiration is calculated by

$$PET = K\ PET(0)$$

in which K is a constant for each month of the year, varying as a function of latitude. The latitude for Fort Erie station is 42º 53’ and values of K are provided in **Table B.2** in **Appendix B**.

Water Surplus

The overall pre-construction water surplus for study area is estimated at 445 mm/year. Water surplus (S) has two components in Thornthwaite model: a runoff component, which is the overland flow component that occurs when soil moisture capacity is exceeded; and, an infiltration component. Using the MECP SWM manual (MECP, 2003) for guidance, it is estimated that about 50% of the water surplus (222.5 mm/year) infiltrates and the remaining 50% (222.5 mm/year) runs off either directly or as interflow. The details calculation is presented in **Table B.2** in **Appendix B**.

Annual Water Balance

The summary of annual water balance assessment for the pre-construction condition is provided in **Table B.3** in **Appendix B**.

2.3 Post-Construction Water Balance without LID

Based on the proposed Draft Plan provided by the Client (**Appendix A**), **Table 1** below shows a summary of post (proposed) construction land statistics.

Table 1: Post-Construction (Proposed) Land Statistics

Item	Area (m^2)
Total Area	81,500
Paved municipal roadways	10,500
Sidewalks	1,000
Townhouse driveways	2,700
Roofs	9,450
Soft landscaped lot lawns, Boulevards, Park, woodland, Open space, and (excluding SWM Pond)	56250
SWM Pond (30% of Block 18)	8,580

To predict water balance elements, the 30-year average weather data was used. Based on the provided development information, it is our understanding that about 30% of the post construction surface will be considered impervious. Additionally, the Conservation Authority guidelines suggest infiltration will be lowered by 10% (a factor of 0.1) because of site grading and compaction of the soil due to construction work. However, the soil compaction issue might be resolved by increasing the topsoil depth to 300 mm. **Table B.4** in **Appendix B** presents the components of post construction water balance.

Precipitation (P)

Precipitation remains the same, the 30-year average (1981-2010) for the Fort Erie meteorological station (1051.5 mm/year) was used.

Storage (ST)

Long-term change in storage is 0. It should be noted that compared to pre-construction, there is a change in the distribution and magnitude of monthly soil moisture storage. It is assumed that development of the land will result in reduced grades that, with the same soil conditions (clayey silt to sandy silt till) and changed vegetative cover (shallow rooted lawns and gardens), will reduce the maximum soil moisture storage to 125 mm.

Evapotranspiration

In post construction, it was assumed that the increased impervious area would result in an additional 20% in potential evaporation from the areas covered with hard surfaces. The total water lost to evaporation increases, but the PET for pervious areas, calculated at 607 mm/year, remains about the same.

Water Surplus

The post-construction water surplus for the entire Site is calculated to be about 1,286 mm/year. Of this, about 707 mm/year will be converted to runoff on impervious areas and 579 mm/year will be available for infiltration or runoff on pervious areas in post-development condition. This exceeds the infiltration potential for the surficial soils, thus a component of the available infiltration water will also run off.

The results of the post construction water balance calculation suggest that there is enough water to maintain recharge, as there is a positive surplus (S) in the post construction scenario.

The major change between the pre- and post-construction water balance is that in the pre-construction setting, most of the water surplus is carried off the site as interflow and infiltration, whereas in the post construction setting, there is more interflow and overland flow. **Table B.5** in **Appendix B** shows that the volume of runoff will be increased from 25,551 m^3/year in pre-development to 32,287 m^3/year. The post-development infiltration volume is approximately 13,761 m^3/year which is almost 89% of the pre-development, if no mitigation measure is implemented and 30% of the site surface is converted to impervious surface.

2.4 Post-Construction Water Balance with LID

To assess the potential impacts of the proposed development on groundwater resources, the draft development plan was reviewed.

Table B.6 in **Appendix B** presents the overall post construction water balance with mitigation measures.

Post development infiltration and runoff rates will be affected by the presence of impervious surfaces (i.e. building/garage rooftops, asphalt driveways and road), which based on the proposed development plan will comprise approximately 30% of the development property. The results of the post-construction water balance assessment without LID measures (**Table B.5** in **Appendix B**) show that there will be enough water to infiltrate in the pervious areas to increase the infiltration rate and reduce the runoff in post-construction development. Techniques to maximize the water availability in pervious areas such as designing grades to direct roof runoff towards lawns, side and rear yard swales, and other pervious areas throughout the development where possible can considerably increase the volume of infiltration in developed areas. Increasing the topsoil thickness by about two times the normal thickness is also considered as beneficial to enhance storage of water in the topsoil and increase the potential for infiltration. Other mitigation techniques that can be considered to mitigate increases in runoff and reductions in infiltration include such measures as subsurface infiltration trenches, permeable pavements, rain gardens, bioswales, galleries and pervious pipe systems. Surface methods should only be considered in areas where there is sufficient depth to water table to accommodate the systems within the unsaturated zone and sufficient soil hydraulic conductivity to function effectively. The MECP manual recommends that subsurface galleries or trenches should be about 1 m above the high water table.

The proposed LID measures for the Site would be the disconnected roof leaders to convey the rainwater from roofs to the permeable areas around the residential houses and increase the chance of infiltration.

It was considered that LID measures would be designed to infiltrate the 25 mm storm event or less which accounts for approximately 90% of precipitation. The estimated infiltration rate for the roof rainfall, then, calculated based on the followings:

- 20% of the rainfall on impervious surface (roofs) was assumed to be evaporated. It means there is 80% or 841 mm surplus.
- 90% of the rainfall event is 25 mm or less. Only 90% of the surplus was considered for infiltration (757.1 mm).
- The estimated infiltration rate on pervious areas is 45% in post-construction condition (MECP Guideline, 2003). The total infiltration rate from roof rains would be 341 mm or 32.4% of the precipitation.

Natural infiltration that occurs on pervious surfaces along with the proposed mitigative measures exceed the pre-development infiltration volume by approximately 1,524 m^3/year. The runoff volume also exceeds the pre-development runoff volume by approximately 3,728 m^3/year.

In this condition, the total infiltration volume will be 16,980 m^3/year and total runoff volume in the post-construction will be changed to 29,279 m^3/year. **Table 2** below summarizes the post-construction water balance for reducing the runoff and increasing infiltration using LID measures.

Table 2: Post -Construction Water Balance Summary

Parameter	Value
Average Annual Rainfall (mm)	1,051.5
Pre- Development Infiltration (m^3/year)	15,457
Post-Development Infiltration without Mitigation (m^3/year)	13,761
Post-Development Infiltration with Mitigation (m^3/year)	16,980
Pre- and Post-Development Infiltration Differential (%)	+10%

3 IMPACT ASSESSMENT

To assess the potential impacts of the proposed development on groundwater resources, the draft development plan was reviewed. From a hydrogeological perspective, the following changes will occur as a result of the proposed development.

- The subject site is characteristically homogeneous with respect to soil types at ground surface. There is a shallow overburden with approximate thickness of 5 to 6 m above bedrock.
- The development will create new hard surfaces over a portion of the site, increasing the impervious area. The amount of impervious areas is estimated to be about 30%.
- As a result of the increase in impervious area, the overall infiltration will decrease and the amount of overland flow runoff will increase, particularly during storm events. Runoff will be managed using conventional storm water management techniques or Low Impact Development (LID) that include storm water management (SWM) facilities.
- With the inevitable changes in impervious areas and potential changes to groundwater quality and quantity, best management practices (BMPs) that promote groundwater infiltration/recharge for the purpose of trying to establish post-development infiltration at pre-development levels makes a significant contribution to mitigate the effects of development. Some of the recommended practices includes:
  - Disconnected roof leaders to convey the rainwater from roofs to the permeable areas around the residential houses and increase the chance of infiltration. The discharge of residential roof drainage to unpaved parts of the lots and grass areas for natural infiltration can be an effective means of helping to balance pre to post development infiltration deficit. Using the roof-tops rainwater can also preserve the groundwater quality. The location of these facilities and the function/operation are addressed by others.
- Although, the increase in impervious area can potentially result in a slight lowering of shallow groundwater levels, maintaining infiltration at levels similar to existing conditions will result water levels within the current range of seasonal fluctuations. No change in the overall flow direction is expected. However, in localized areas some temporary lowering of the water table may be needed to facilitate construction below the water table, if required.
- The contribution of groundwater can be an important factor in the overall health of aquatic systems. Implementing mitigation measures to reduce the infiltration deficit will assist in maintaining the current level of groundwater contribution to the surface water features. As such, no negative impact is expected if LID measures are implemented to maintain the groundwater recharge similar to the existing conditions.

4 STATEMENT OF LIMITATIONS

The contents of this report are subject to the attached '***Statement of Limitation***' sheet. The reader's attention is specifically drawn to these conditions as it is considered essential that they be followed for proper use and interpretation of this report. The Statement of Limitations is not intended to reduce the level of responsibility accepted by Orbit, but rather to ensure that all parties who have been given reliance for this report are aware of the responsibilities each assumes in so doing.

This report was prepared by HLV2K exclusively for the account of SS Welland Inc. (the CLIENT). Other than by the CLIENT, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, or decision made by any person other than CLIENT based on this report is the sole responsibility of such other person. The CLIENT and Orbit make no representation or warranty to any other person with regard to this report and the work referred to in this report and the CLIENT and Orbit accept no duty of care to any other person or any liability or responsibility whatsoever for any losses, expenses, damages, fines, penalties or other harm that may be suffered or incurred by any other person as a result of the use of, reliance on, any decision made or any action taken based on this report or the work referred to in this report.

5 CLOSURE

We trust that this information is satisfactory for your present requirements. Should you have any questions or require additional information, please do not hesitate to contact this office.

For and Behalf of HLV2K Engineering Limited

Kourosh Mohammadi, PhD., P.Eng.

Principal Hydrogeological Engineer and Groundwater Modeller

REFERENCES

Conservation Authority (2013). Hydrogeological Assessment Submissions: Conservation Authority Guideline to Support Development Applications.

Environment Canada (2017) Canadian National Climate Archive, Canadian Climate Norms and Averages (1981 – 2010), Fort Erie – Station ID 6132470 – Website: https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProx&txtRadius=25&selCity=&selPark=&optProxType=custom&txtCentralLatDeg=42&txtCentralLatMin=53&txtCentralLatSec=0&txtCentralLongDeg=78&txtCentralLongMin=56&txtCentralLongSec=0&txtLatDecDeg=&txtLongDecDeg=&stnID=4635&dispBack=0

HLV2K Engineering Limited. (2021). Hydrogeological Investigation for Proposed Development at 613 Helena Street, Fort Erie, Ontario, Project Number 2100394AG, dated November 2021.

Mather, J. R., 1978. The Climatic Water Budget in Environmental Analysis. Lexington, Mass.: Lexington Books.

MECP (2003). Stormwater Management Planning and Design Manual, Ontario Ministry of Environment, 379p.

HLV2K Engineering Limited

STATEMENT OF LIMITATIONS

Your report has been developed based on your unique project specific requirements as understood by HLV2K Engineering Limited (HLV2K) and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking HLV2K to assess how factors that changed subsequent to the date of the report affect the report's recommendations. HLV2K cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions, which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult HLV2K to be advised how time may have impacted on the project.

The findings derived from this investigation were based on information collected and/or provided by the Client. It may become apparent that soil and groundwater conditions differ between and beyond the testing locations examined during future investigations or other work that could not be detected or anticipated at the time of this study. As such, HLV2K cannot be held liable for environmental conditions that were not apparent from the available information. The conclusions presented represent the best judgment of the assessors based on limited investigations.

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature, external data source review, sampling, and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions, which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of HLV2K through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report is based on the assumption that he site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only HLV2K, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and HLV2K cannot be held responsible for such misinterpretation.

To avoid misuse of the information contained in your report it is recommended that you confer with HLV2K before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

HLV2K Engineering Limited

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain HLV2K to work with other project design professionals who are affected by the report. Have HLV2K explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment.

Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact HLV2K for information relating to geoenvironmental issues.

HLV2K is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with HLV2K to develop alternative approaches to problems that may be of genuine benefit both in time and in cost.

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from HLV2K to other parties but are included to identify where HLV2K's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from HLV2K closely and do not hesitate to ask any questions you may have.

Third party information reviewed and used to formulate this report is assumed to be complete and correct. HLV2K used this information in good faith and will not accept any responsibility for deficiencies, misinterpretation or incompleteness of the information contained in documents prepared by third parties.

Nothing in this report is intended to constitute or provide a legal opinion.

Should additional information become available, HLV2K requests that this information be brought to our attention so that we may re-assess the conclusions presented herein.

FIGURES

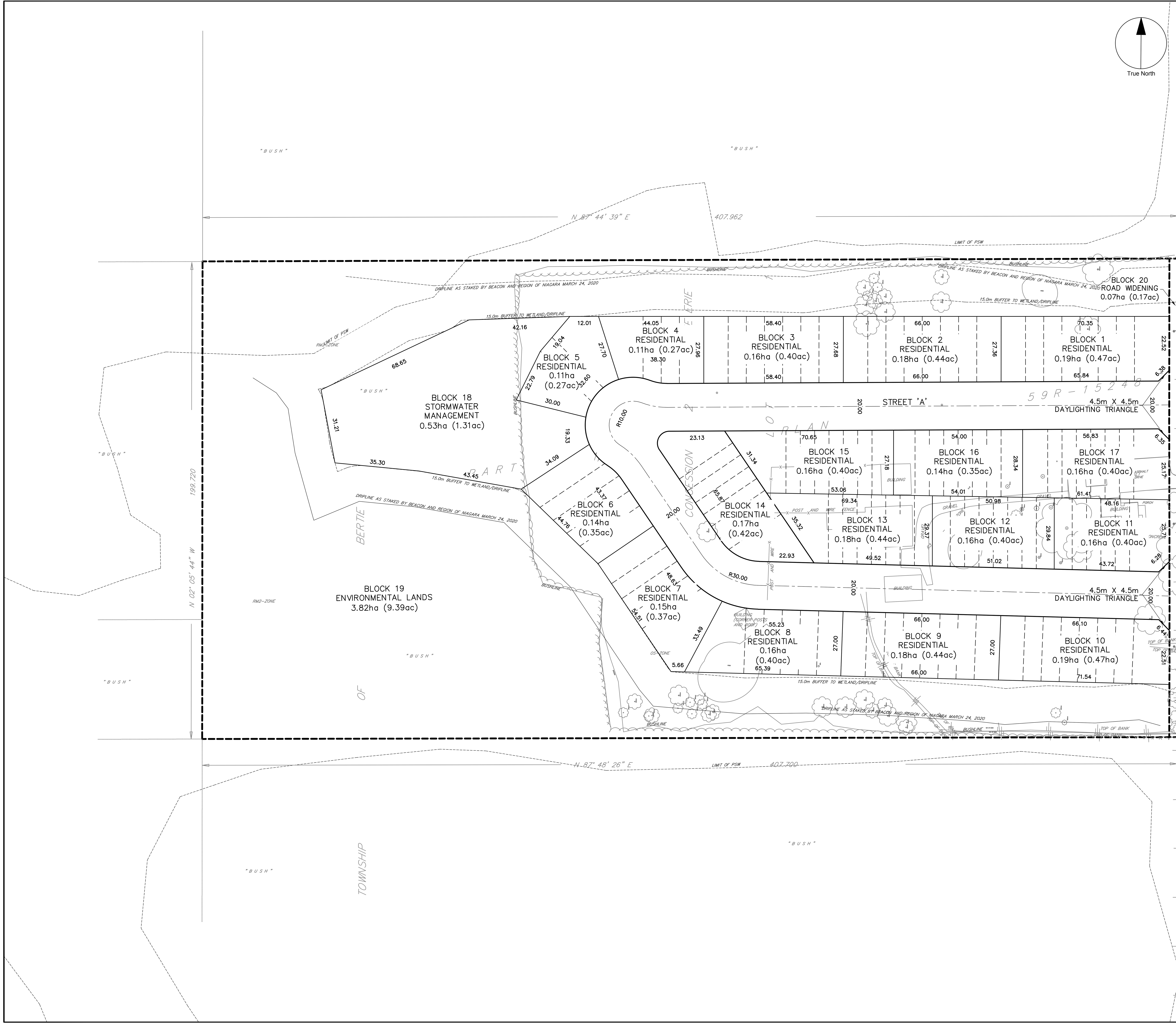
Legend

Approx. Site Boundary

Drawn: MM	Title: SITE LOCATION PLAN
Approved: KM	Project: WATER BALANCE STUDY Proposed Residential Development 613 Helena Street, Fort Erie, Ontario
Date: NOV. 2021	
Project No.: 2100394AG	
	Client: SS WELLAND INC.
HLV2K ENGINEERING LIMITED	0 125 250 500 Meters — FIGURE 1

APPENDIX A

Drawing Provided by the Client



LAND USE SCHEDULE		
BLOCKS	DESCRIPTION	AREA (ha)
BLOCKS 1-17	RESIDENTIAL	2.70
BLOCK 18	STORMWATER MANAGEMENT	0.53
BLOCK 19	ENVIRONMENTAL LANDS	3.82
BLOCK 20	ROAD WIDENING	0.07
R.O.W.	STREET 'A'	1.02
TOTAL AREA		8.14

DRAFT PLAN OF SUBDIVISION 613 HELENA STREET

PART OF LOT 1, CONCESSION 2,
LAKE ERIE TOWNSHIP OF BERTIE
IN THE TOWN OF FORT ERIE
REGIONAL MUNICIPALITY OF NIAGARA

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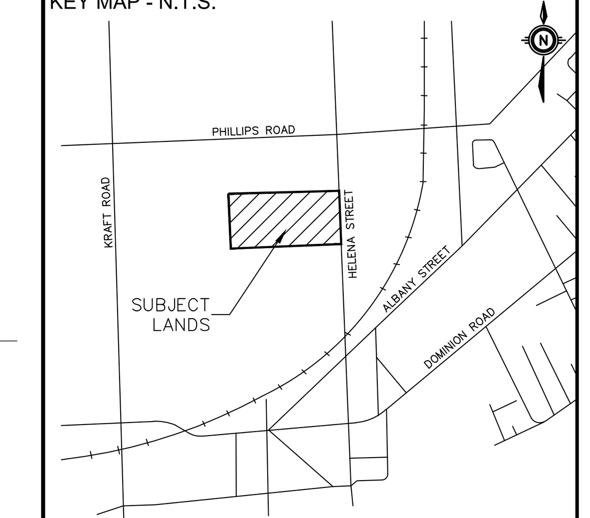
KEY MAP - N.T.S.



INFORMATION REQUIRED

UNDER SECTION 51 (17) OF THE PLANNING ACT, R.S.O. 1990. c.P.13 AS AMENDED

(a) - AS SHOWN
(b) - AS SHOWN
(c) - AS SHOWN
(d) - RESIDENTIAL
(e) - AS SHOWN
(f) - AS SHOWN
(g) - AS SHOWN
(h) - MUNICIPAL (PUBLIC)
(i) - SILTY CLAY
(j) - AS SHOWN
(k) - ALL SERVICES TO BE MADE AVAILABLE
(l) - AS SHOWN

SURVEYOR'S CERTIFICATE

I HEREBY CERTIFY THAT THE BOUNDARIES OF THE LANDS TO BE SUBDIVIDED ON THIS PLAN AND THEIR RELATIONSHIP TO THE ADJACENT LANDS ARE ACCURATELY AND CORRECTLY SHOWN.

SIGNED ____________
PHILIP S. SUDA, O.L.S.
SUDA & MALESZYK SURVEYING INC.

DATE ____________

OWNER'S CERTIFICATE

I HEREBY CONSENT TO THE FILING OF THIS PLAN BY IBI GROUP, IN DRAFT FORM.

SIGNED ____________
MARIO BEVACQUA
1891187 ONTARIO INC.

DATE ____________

#	DATE	BY	DESCRIPTION
1			

DRAWING ISSUE RECORD

APPROVALS

IBI GROUP
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Hamilton ON L8L 1H5 Canada
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ibigroup.com

BENCHMARK

SCALE 10 5 0 10 20 30
1:750 (m)

PROJECT NO: 131951	
DRAWN BY: T. NGUYEN	CHECKED BY: T. TUCKER
PROJECT MGR: T.TUCKER	APPROVED BY:

SHEET TITLE
DRAFT PLAN OF SUBDIVISION

SHEET NUMBER DP 1.0 — ISSUE 1

Plotted: Thursday, April 8, 2021 10:39:00 AM by Tracy Tucker

APPENDIX B

Water Balance Tables

TABLE B.1 - Climate Data

Fort Erie Station, Ontario

Latitude: 42°53' N   Longitude: 79°58' W   Elevation: 179.80 m

Temperature: Temperature:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	-4.1	-3.3	0.4	6.6	12.7	18.1	21.2	20.6	16.7	10.4	4.9	-0.8	8.6
Rainfall (mm)	34.2	32.8	44.7	74.4	92.3	81.7	84.7	88.5	105.4	95.3	89.9	52.5	876.4
Snowfall (mm)	44.7	33.8	26.3	4.4	0.9	0.0	0.0	0.0	0.0	1.4	12.9	50.7	175.1
Precipitation (mm)	78.9	66.6	71.0	78.8	93.2	81.7	84.7	88.5	105.4	96.7	102.8	103.2	1051.5

TABLE B.2

Pre- and Post-Development Water Balance Components
Based on Thornthwaite's Soil Moisture Balance Approach

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Davily Average Temperature (^oC)	-4	-3	0	7	13	18	21	21	17	10	5	-1	9
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.02	1.52	4.10	7.01	8.91	8.53	6.21	3.03	0.97	0.00	**40.3**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	0.00	27.94	58.53	87.36	104.44	101.11	79.76	46.70	19.95	0.00	**526**
Adjusting Factor K for U (Latitude 42^o 53' N)	0.77	0.88	0.99	1.11	1.22	1.28	1.26	1.17	1.05	0.92	0.81	0.75	
Adjusted Potential Evapotranspiration PET (mm)	0	0	0	31	72	112	131	118	83	43	16	0	**607**
PRE-DEVELOPMENT WATER BALANCE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	79	67	71	79	93	82	85	89	105	97	103	103	1052
Potential Evapotranspiration (PET)	0	0	0	31	72	112	131	118	83	43	16	0	607
P - PET	79	67	71	48	22	-30	-47	-30	22	54	87	103	445
Change in Soil Moisture Storage	0	0	0	0	0	-30	-47	-30	22	54	31	0	**0**
Soil Moisture Storage (Assume January Soil Moisture Storage = 100% SMS)	250	250	250	250	250	220	173	143	165	219	250	250	
Actual Evapotranspiration (AET)	0	0	0	31	72	112	131	118	83	43	16	0	607
Soil Moisture Deficit (in mm)	0	0	0	0	0	30	77	107	85	31	0	0	
Surplus - available for infiltration or runoff	79	67	71	48	22	0	0	0	0	0	56	103	**445**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	39.5	33.3	35.5	23.9	10.8	0.0	0.0	0.0	0.0	0.0	27.9	51.6	222
Potential Surface Water Runoff (independent of temperature)	39.5	33.3	35.5	23.9	10.8	0.0	0.0	0.0	0.0	0.0	27.9	51.6	222
POST- DEVELOPMENT WATER BALANCE ON IMPERVIOUS AREAS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	79	67	71	79	93	82	85	89	105	97	103	103	1052
Potential Evaporation (PE) from impervious areas (assume 20%)	15.8	13.3	14.2	15.8	18.6	16.3	16.9	17.7	21.1	19.3	20.6	20.6	210
P-PE (surplus available from impervious areas)	63	53	57	63	75	65	68	71	84	77	82	83	841
Water surplus change compared to pre-condition (for areas that change from vegetated open areas to impervious areas)	-16	-13	-14	15	53	65	68	71	84	77	27	-21	396

Soil Moisture Storage	250
PE from impervious areas %	20

*MOE SWM infiltration factor calculation	
topography - Flat aland, average slope <0.6 m/km	0.3
soils - relatively tight silty clay till materials	0.1
cover - predominantly cultivated land	0.1
Infiltration Factor	0.5

TABLE B.3 - Annual Pre-Construction Water Balance

	Pre-Construction		
	Unpaved Areas	Impervious Areas (building)	Totals
Area	69500	12000	81500
Pervious Area	69500	0	69500
Impervious Area	0	12000	12000
Infiltration Factors			
Topography Infiltration Factor	0.3	0	
Soil Infiltration Factor	0.1	0	
Land Cover Infiltration Factor	0.1	0	
MOE Infiltration Factor	0.5	0	
Actual Infiltration Factor	0.5	0	
Runoff Coefficient Pervious Surfaces	0.5	1	
Runoff from Impervious Surfaces*	0	0.8	
Inputs (per Unit Area)			
Precipitation (mm/yr)	1052	1052	1052
Run-On (mm/yr)	0	0	0
Other Inputs (mm/yr)	0	0	0
Total Inputs (mm/yr)	1052	1052	1052
Outputs (per Unit Area)			
Precipitation Surplus (mm/yr)	445	841	503
Net Surplus (mm/yr)	445	841	503
Evapotranspiration (mm/yr)	607	210	548
Infiltration (mm/yr)	222	0	190
Rooftop Infiltration (mm/yr)	0	0	0
Total Infiltration (mm/yr)	222	0	190
Runoff Pervious Areas	222	0	190
Runoff Impervious Areas	0	841	124
Total Runoff (mm/yr)	222	841	314
Total Outputs (mm/yr)	1052	1052	853
Difference (Inputs - Outputs)	0	0	
Inputs (Volumes)			
Precipitation (m3/yr)	73079	12618	85697
Run-On (m3/yr)	0	0	0
Other Inputs (m3/yr)	0	0	0
Total Inputs (m3/yr)	73079	12618.0	85697
Outputs (Volumes)			
Precipitation Surplus (m3/yr)	30913	10094	41008
Net Surplus (m3/yr)	30913	10094	41008
Evapotranspiration (m3/yr)	42166	2524	44689
Infiltration (m3/yr)	15457	0	15457
Rooftop Infiltration (m3/yr)	0	0	0
Total Infiltration (m3/yr)	15457	0	**15457**
Runoff Pervious Area (m3/yr)	15457	0	15457
Runoff Impervious Areas (m3/yr)	0	10094	10094
Total Runoff (m3/yr)	15457	10094	**25551**
Total Outputs (m3/yr)	73079	12618	85697
Difference (Inputs - Outputs)	0	0	0

* Evaporation from impervious areas was assumed to be 20% of precipitation

TABLE B.4 - WATER BALANCE COMPONENTS FOR CASE WHERE RUNOFF IS DIRECTED TO PERVIOUS AREAS

POTENTIAL EVAPOTRANSPIRATION CALCULATION	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (^{o} C)	-4.1	-3.3	0.4	6.6	12.7	18.1	21.2	20.6	16.7	10.4	4.9	-0.8	8.6
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.02	1.52	4.10	7.01	8.91	8.53	6.21	3.03	0.97	0.00	**40.3**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	0.00	27.94	58.53	87.36	104.44	101.11	79.76	46.70	19.95	0.00	**526**
Adjusting Factor K for U (Latitude 42o 53' N)	0.77	0.88	0.99	1.11	1.22	1.28	1.26	1.17	1.05	0.92	0.81	0.75	
Adjusted Potential Evapotranspiration PET (mm)	0	0	0	31	72	112	131	118	83	43	16	0	**607**
POST-DEVELOPMENT WATER BALANCE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Pervious areas will receive rainfall plus some runoff from impervious areas, so the following balance calculations use this total water supply to assess potential infiltration.													
Precipitation (P)	79	67	71	79	93	82	85	89	105	97	103	103	1052
Potential Evaporation (PE) from impervious areas (assume 20% of P)	16	13	14	16	19	16	17	18	21	19	21	21	210
P-PE (surplus available for runoff from impervious areas)	63	53	57	63	75	65	68	71	84	77	82	83	**841**
WAT (Total water supply to pervious areas = rain plus impervious area runoff)	142	120	128	142	168	147	152	159	190	174	185	186	**1893**
Potential Evapotranspiration from pervious areas (PET)	0	0	0	31	72	112	131	118	83	43	16	0	**607**
WAT - PET	142	120	128	111	96	35	21	41	106	131	169	186	**1286**
Change in Soil Moisture (mm)	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Soil Moisture Storage (mm)*	125	125	125	125	125	125	125	125	125	125	125	125	
Actual Evapotranspiration (AET)	0	0	0	31	72	112	131	118	83	43	16	0	**607**
Total surplus - available for infiltration or runoff on pervious areas	142	120	128	111	96	35	21	41	106	131	169	186	**1286**
Estimate of I and R (based on MOE infiltration factor)*													
Potential Infiltration* (based on soil conditions; independent of temperature)	63.9	53.9	57.5	49.9	43.3	15.8	9.4	18.6	47.8	59.0	76.0	83.6	**579**
Potential Surface Water Runoff (independent of temperature)	78.1	65.9	70.3	60.9	52.9	19.3	11.5	22.7	58.5	72.1	92.9	102.2	**707**
Estimate of I and R (based on MOE Factors and CA Guideline assumption of a 10% reduction in infiltration reduction related to soil compaction)													
Potential Infiltration (based on soil conditions; independent of temperature)	57.5	48.6	51.8	44.9	38.9	14.2	8.5	16.7	43.1	53.1	68.4	75.2	**521**
Potential Surface Water Runoff (independent of temperature)	84.5	71.3	76.0	65.9	57.2	20.9	12.5	24.6	63.3	78.0	100.5	110.5	**765**

Max SMS	125
PE from impervious areas %	20

*MOE SWM infiltration factor calculation	
topography - flat to rolling	0.25
soils - tight sandy to clayey silt till	0.1
cover - predominantly impervious paved surface	0.1
Infiltration Factor	0.45

TABLE B.5 - Annual Post-Construction Water Balance without LID

	Unpaved Areas	Impervious Areas (Paved/Buildings)	Water (Pond)	Totals
Area	56250	23650	1600	81500
Pervious Area	56250	0	0	56250
Impervious Area	0	23650	1600	25250
Infiltration Factors				
Topography Infiltration Factor	0.25	0	0	
Soil Infiltration Factor	0.1	0	0	
Land Cover Infiltration Factor	0.1	0	0	
MOE Infiltration Factor	0.45	0	0	
Actual Infiltration Factor	0.55	0	0	
Runoff Coefficient Pervious Surfaces	0.45	1	1	
Runoff from Impervious Surfaces*	0	0.8	0.8	
Inputs (per Unit Area)				
Precipitation (mm/yr)	1052	1052	886	1052
Run-On (mm/yr)	0	0	0	0
Other Inputs (mm/yr)	0	0	0	0
Total Inputs (mm/yr)	1052	1052	886	1052
Outputs (per Unit Area)				
Precipitation Surplus (mm/yr)	445	841	841	568
Net Surplus (mm/yr)	445	841	841	568
Evapotranspiration (mm/yr)	607	210	177	483
Infiltration (mm/yr)	245	0	0	169
Rooftop Infiltration (mm/yr)	0	0	0	0
Total Infiltration (mm/yr)	245	0	0	169
Runoff Pervious Areas	200	0	0	138
Runoff Impervious Areas	0	841	709	258
Total Runoff (mm/yr)	200	841	709	396
Total Outputs (mm/yr)	1052	1052	886	1048
Difference (Inputs - Outputs)	0	0	0	
Inputs (Volumes)				
Precipitation (m3/yr)	59147	24868	1418	85432
Run-On (m3/yr)	0	0	0	0
Other Inputs (m3/yr)	0	0	0	0
Total Inputs (m3/yr)	59147	24868	1418	85432
Outputs (Volumes)				
Precipitation Surplus (m3/yr)	25020	19894	1346	46260
Net Surplus (m3/yr)	25020	19894	1346	46260
Evapotranspiration (m3/yr)	34127	4974	284	39384
Infiltration (m3/yr)	13761	0	0	13761
Rooftop Infiltration (m3/yr)	0	0	0	0
Total Infiltration (m3/yr)	13761	0	0	**13761**
Runoff Pervious Area (m3/yr)	11259	0	0	11259
Runoff Impervious Areas (m3/yr)	0	19894	1134	21028
Total Runoff (m3/yr)	11259	19894	1134	**32287**
Total Outputs (m3/yr)	59147	24868	1418	85432
Difference (Inputs - Outputs)	0	0	0	0

* Evaporation from impervious areas was assumed to be 20% of precipitation

TABLE B.6 - Annual Post-Construction Water Balance with LID

	Unpaved Areas (Landscape/ Permeable Pavements)	Impervious Areas (Roads/Buildings)	Buildings with LID (Rooftop Rain)	Water	Totals
Area	56250	14200	9450	1600	81500
Pervious Area	56250	0	0	0	56250
Impervious Area	0	14200	9450	1600	25250
Infiltration Factors					
Topography Infiltration Factor	0.25	0	0	0	
Soil Infiltration Factor	0.1	0	0	0	
Land Cover Infiltration Factor	0.1	0	0	0	
MOE Infiltration Factor	0.45	0	0	0	
Actual Infiltration Factor	0.55	0	0	0	
Runoff Coeffcient Pervious Surfaces	0.45	1	1	1	
Runoff from Impervious Surfaces*	0	0.8	0.8	0.8	
Inputs (per Unit Area)					
Perecipitation (mm/yr)	1052	1052	1052	1052	1052
Run-On (mm/yr)	0	0	0	0	0
Other Inputs (mm/yr)	0	0	0	0	0
Total Inputs (mm/yr)	1052	1052	1052	1052	1052
Outputs (per Unit Area)					
Precipitation Surplus (mm/yr)	445	841	841	841	568
Net Surplus (mm/yr)	445	841	841	841	568
Evapotranspiration (mm/yr)	607	210	210	210	484
Infiltration (mm/yr)	245	0	0	0	169
LID (mm/yr)	0	0	341	0	40
Total Infiltration (mm/yr)	245	0	341	0	208
Runoff Pervious Areas	200	0	0	0	138
Runoff Impervious Areas	0	841	501	841	221
Total Runoff (mm/yr)	200	841	501	841	359
Total Outputs (mm/yr)	1052	1052	1052	1052	1052
Difference (Inputs - Outputs)	0	0	0		
Inputs (Volumes)					
Precipitation (m3/yr)	59147	14931	9937	1682	85697
Run-On (m3/yr)	0	0	0	0	0
Other Inputs (m3/yr)	0	0	0	0	0
Total Inputs (m3/yr)	59147	14931	9937	1682	85697
Outputs (Volumes)					
Precipitation Surplus (m3/yr)	25020	11945	7949	1346	46260
Net Surplus (m3/yr)	25020	11945	7949	1346	46260
Evapotranspiration (m3/yr)	34127	2986	1987	336	39437
Infiltration (m3/yr)	13761	0	0	0	13761
Rooftop Infiltration/Other LID (m3/yr)	0	0	3219	0	3219
Total Infiltration (m3/yr)	13761	0	3219	0	**16980**
Runoff Pervious Area (m3/yr)	11259	0	0	0	11259
Runoff Impervious Areas (m3/yr)	0	11945	4730	1346	18021
Total Runoff (m3/yr)	11259	11945	4730	1346	**29279**
Total Outputs (m3/yr)	59147	14931	9936	1682	85696
Difference (Inputs - Outputs)	0	0	0	0	1

* Evaporation from impervious areas was assumed to be 20% of precipitation